

Application of Reservoir Flow Simulation with Different Fracture Geometries to Improve Hydraulic Fracture Well Performance in Tight Oil Play

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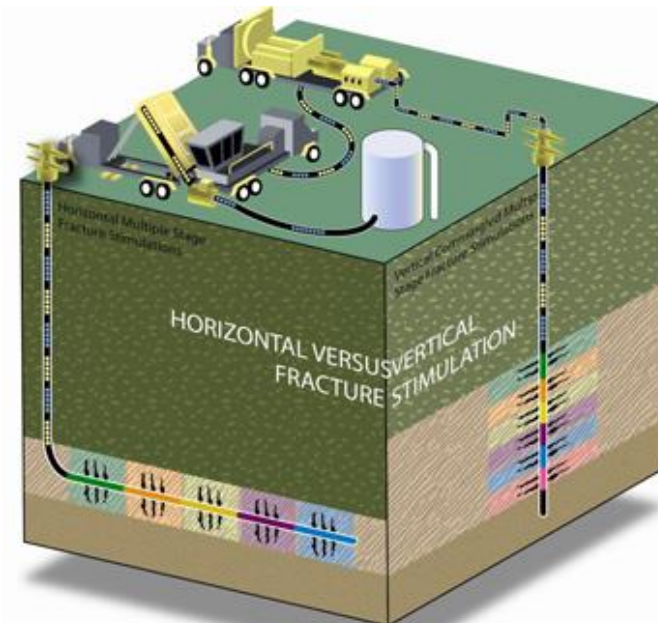
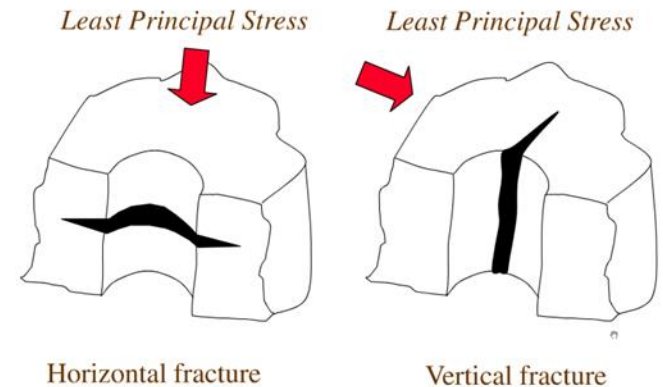
Outline

- **Introduction**
- **Fracture complexity**
- **Modeling approach**
- **Simulation results**
 - Effect of fracture length and conductivity**
 - Effect of fracture geometry**
 - Effect of Secondary Fracture Permeability**
- **Conclusions**

Introduction

❖ Combination of Horizontal wells and Multistage hydraulic Fracturing

- A fluid (commonly water, N₂, etc.) is pumped into the targeted formation until fluid pressure surpasses the rock's strength, creating a new fracture system through which oil and gas can flow into the well.
- Combining multi-stage hydraulic fracturing with horizontal drilling allows a horizontal well to be exposed to just as much reservoir as would a series of singly fractured vertical wells.
- Some companies are now reporting the ability to complete up to 60 fracturing stages in a well.

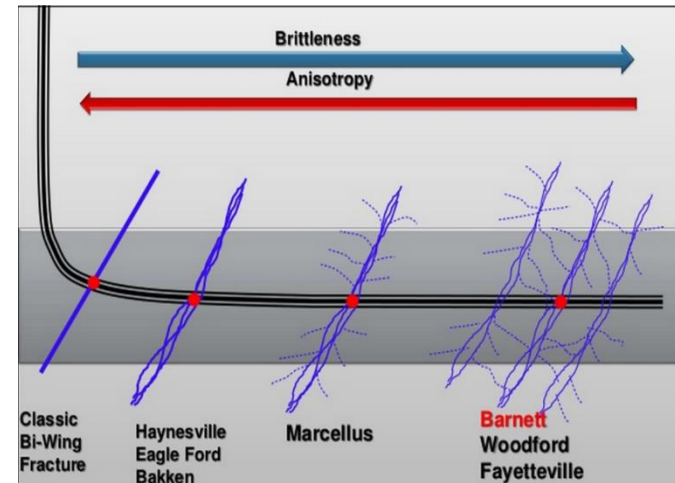


(National Energy Board, 2011)

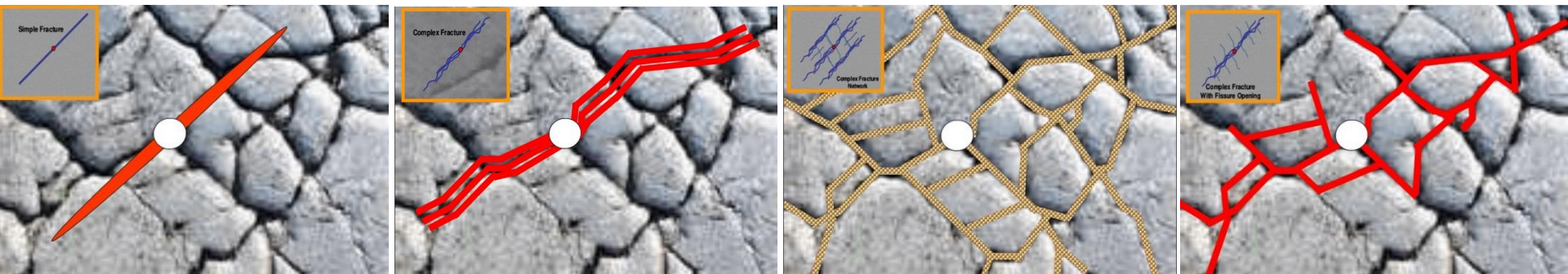
Fracture complexity

❖ Evidence that complex fracture may exist in tight formations

- Natural fractures
- Reservoir heterogeneity / Stress anisotropy
- Microseismic Event
- Tracer data
- History Matching process



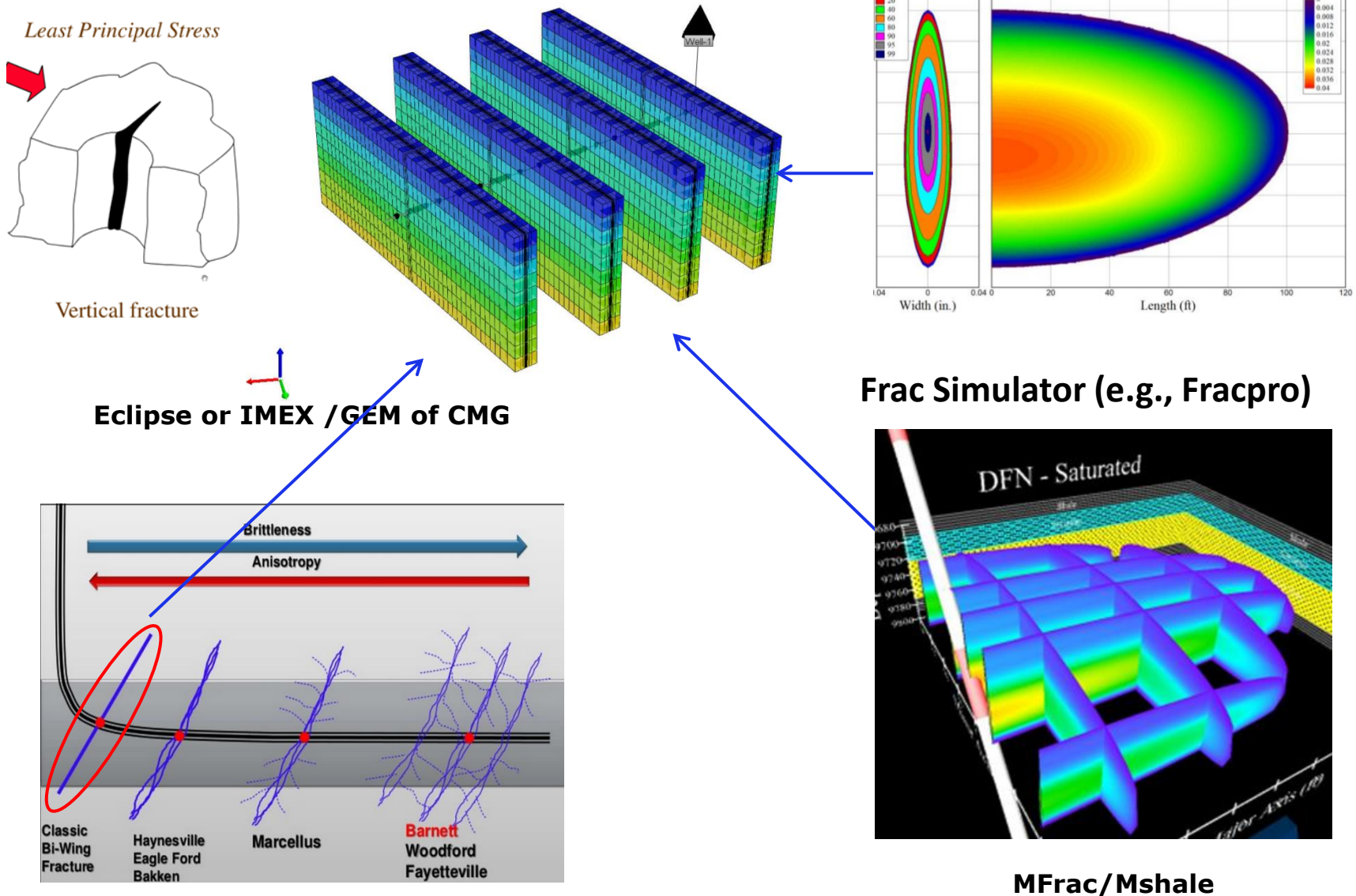
Nejad, 2013



(Warpinski etc., 2008)

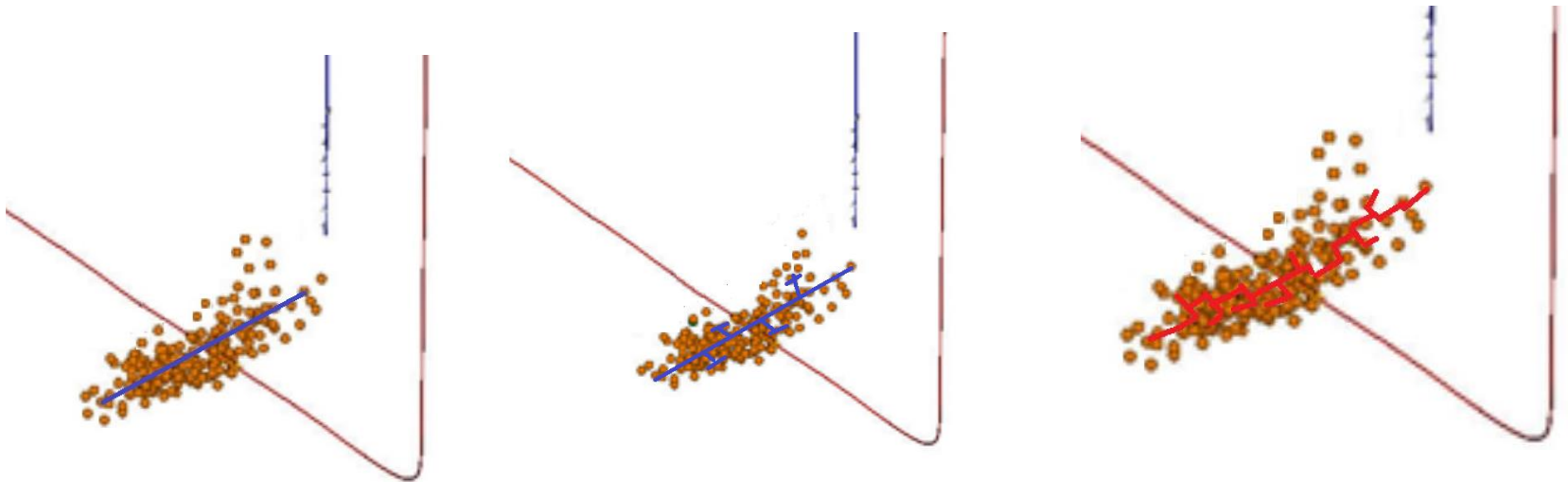
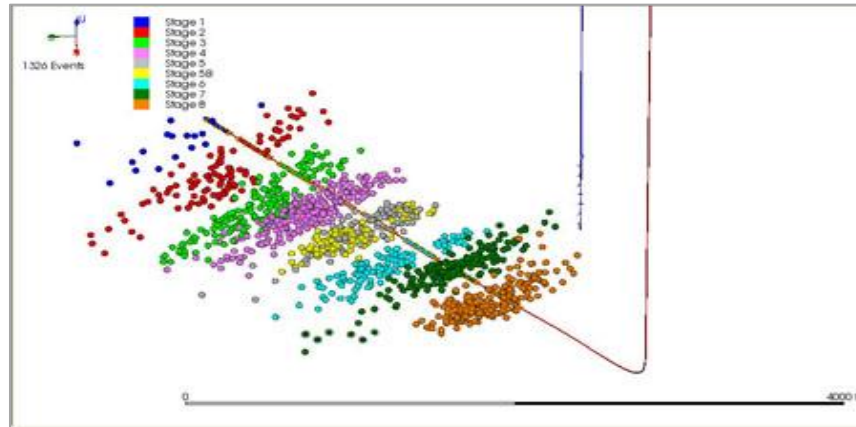
Modeling Approach

❖ How to simulate



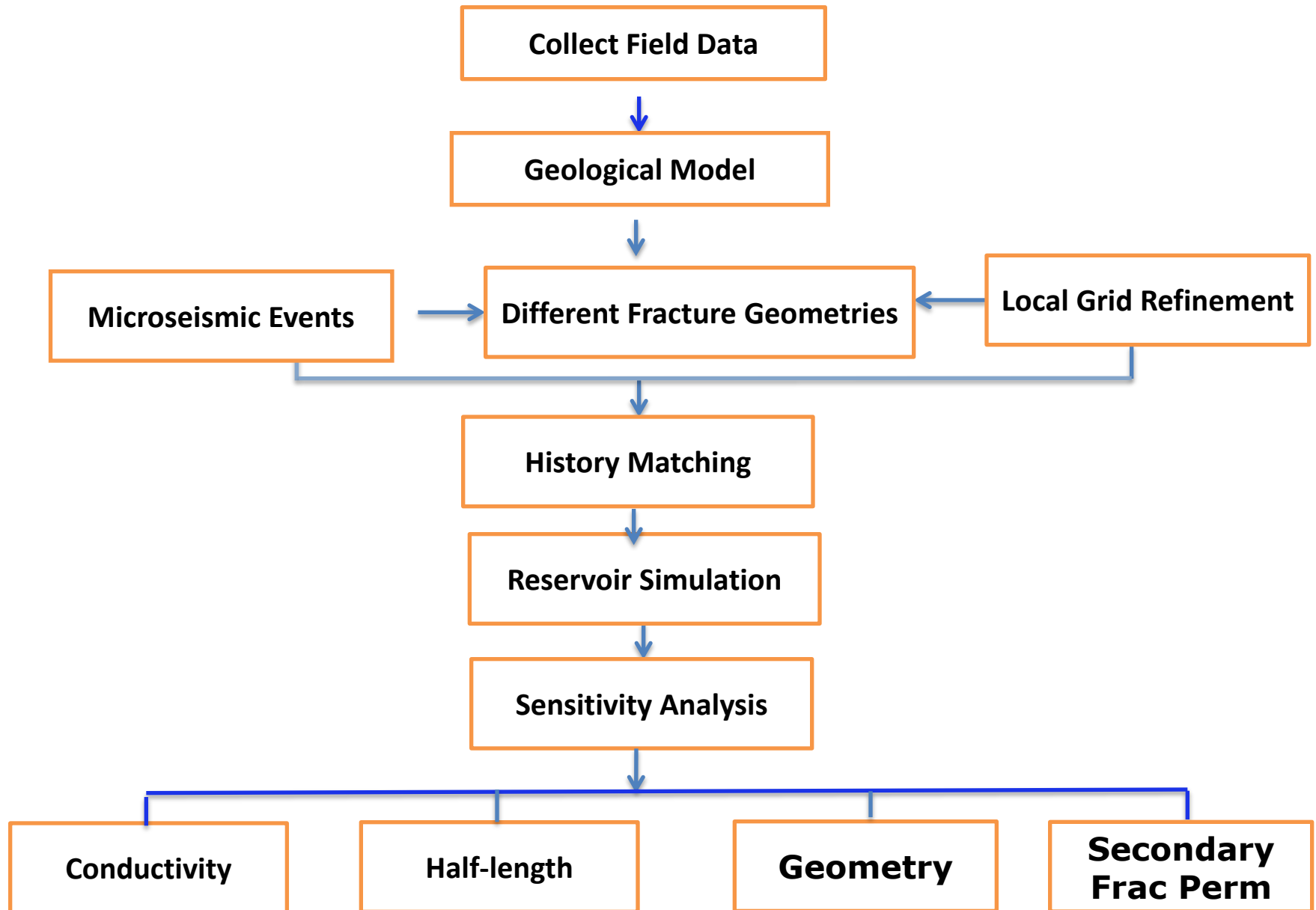
Modeling Approach

- ❖ Constrained by micro-seismic events
- ❖ Same Fracture volume

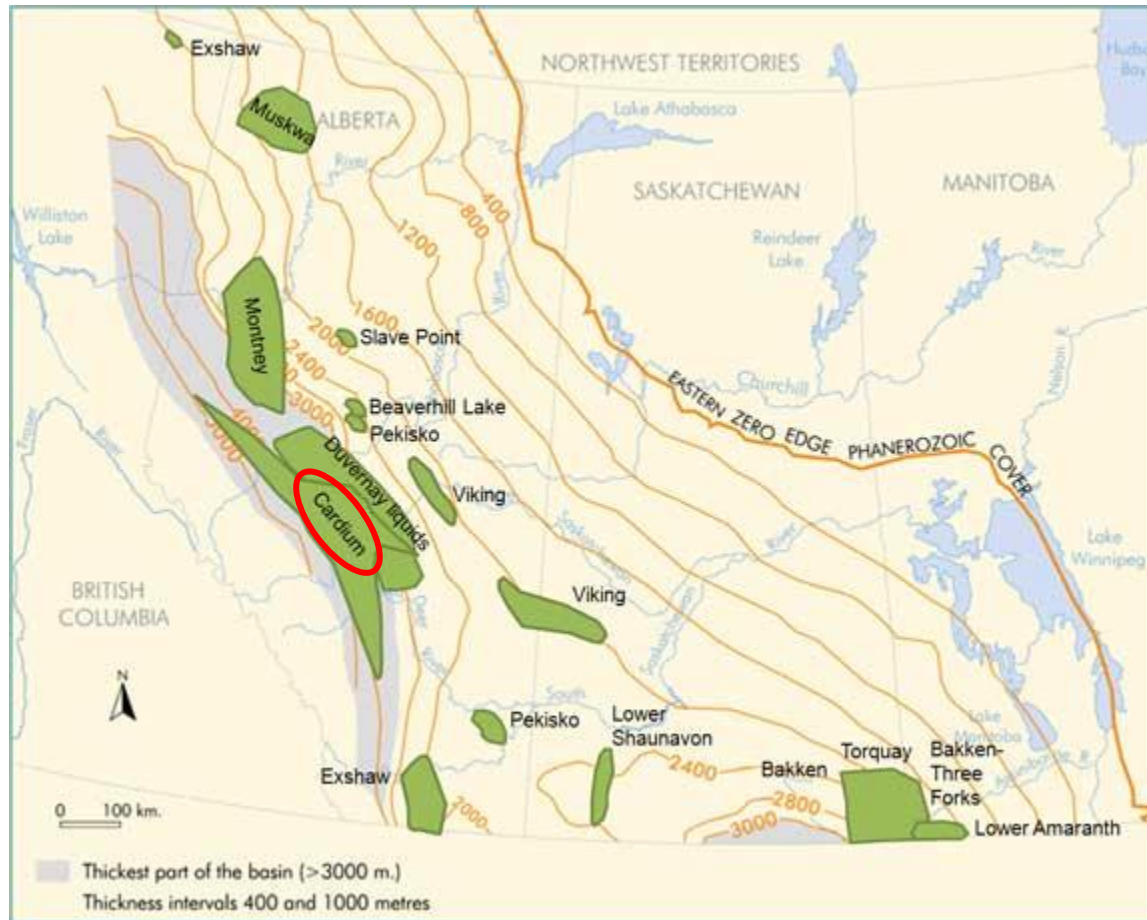


Schematic view of different fracture geometries

Modeling Approach



Modeling Approach(Cont'd)

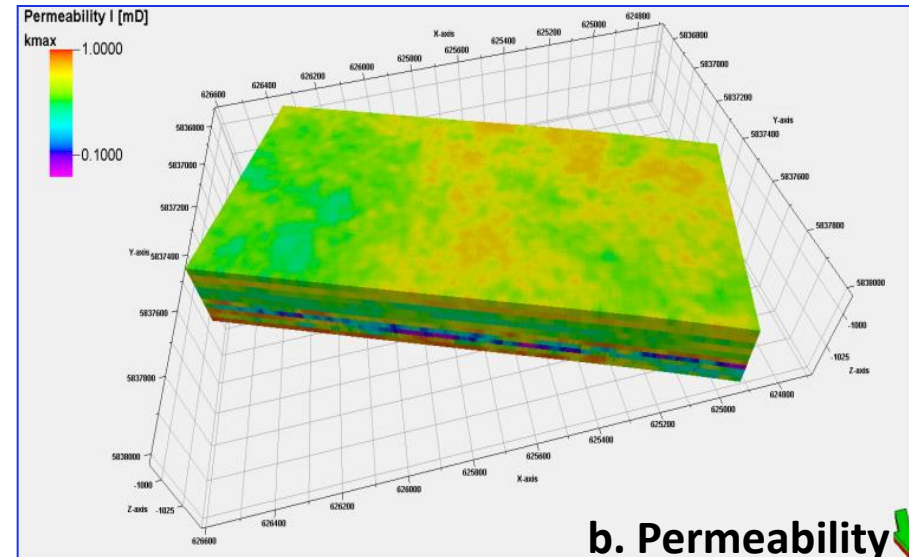
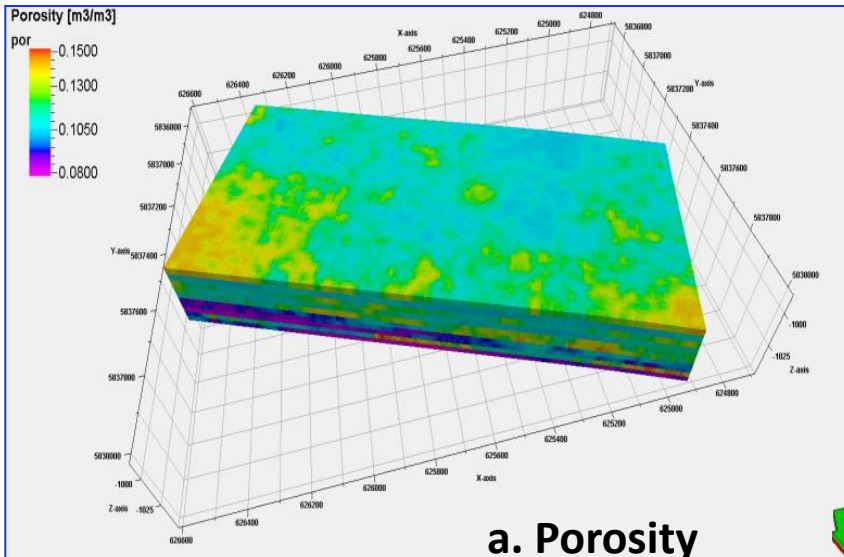


Location of Cardium Formation, Willesden Green Oil Field

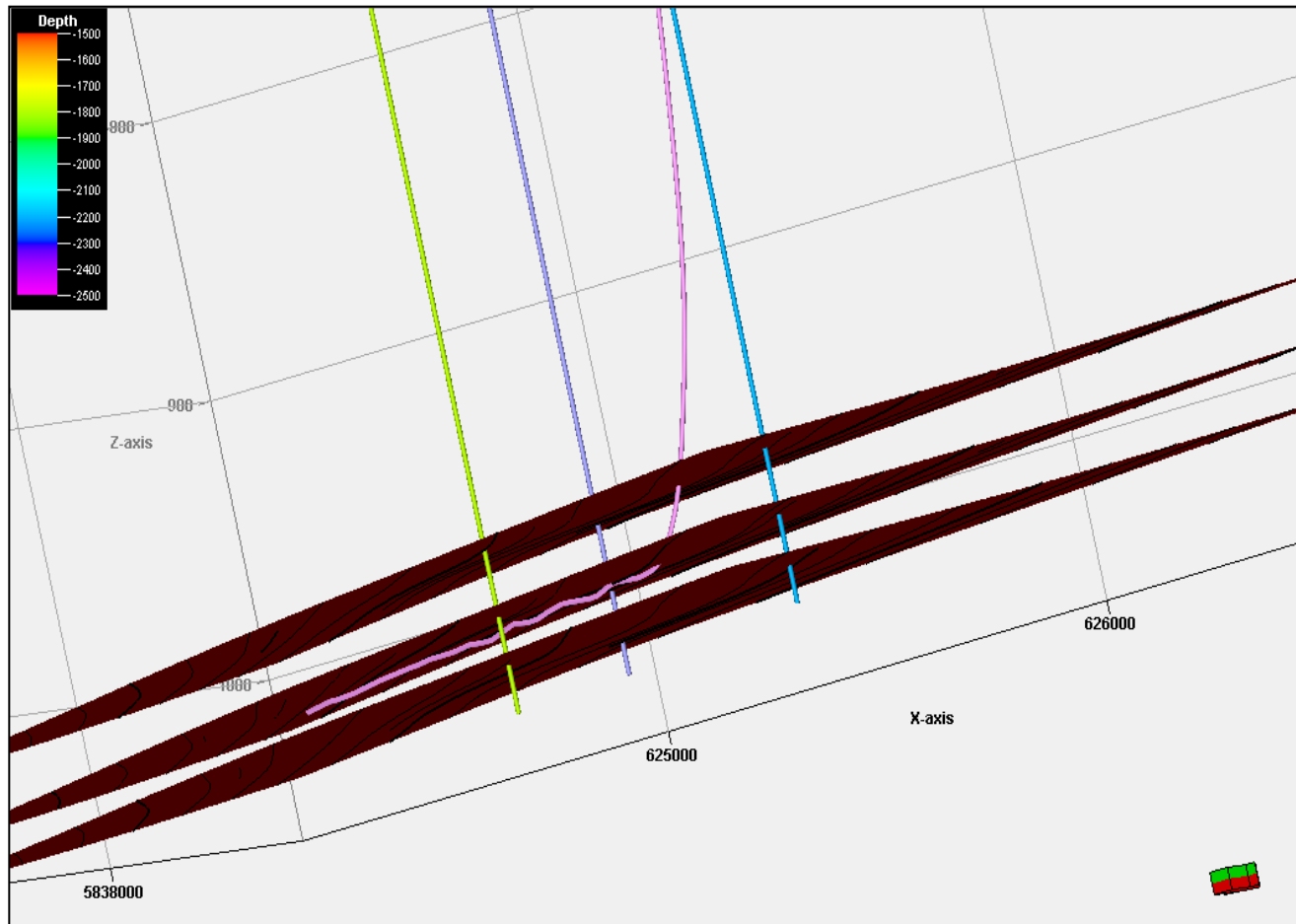
Modeling Approach(Cont'd)

Table 1: Properties of formation and reservoir fluid

Reservoir temperature(°C)	65
Bubble point pressure(MPa)	22.8
Oil density at Stock Tank Condition(API)	30
Gas density at Stock Tank Condition (Air=1)	0.776
Formation compressibility(KPa ⁻¹)	6.41×10^{-7}
Total compressibility(KPa ⁻¹)	2.28×10^{-5}
Reference pressure(MPa)	26.9
Reference depth(m)	2,010
Water-Oil contact(m)	2,040
Solution gas/oil ratio at 23 MPa (Sm ³ /Sm ³)	185
Average production gas/oil ratio (Sm ³ /Sm ³)	1470

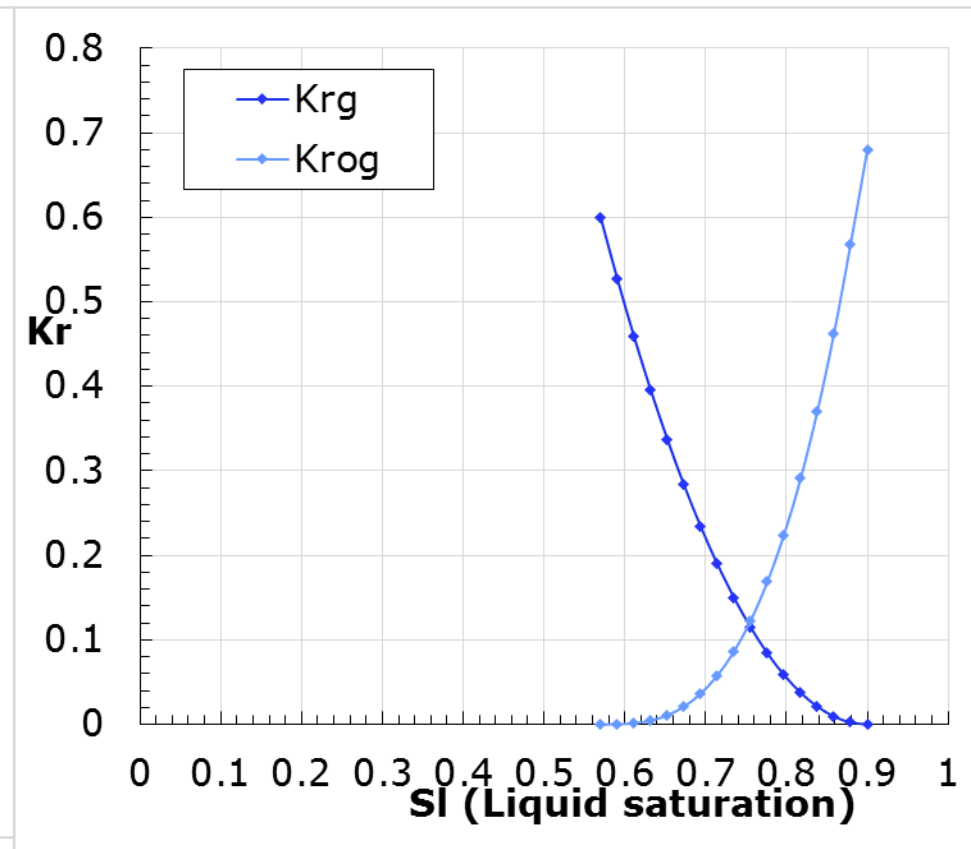
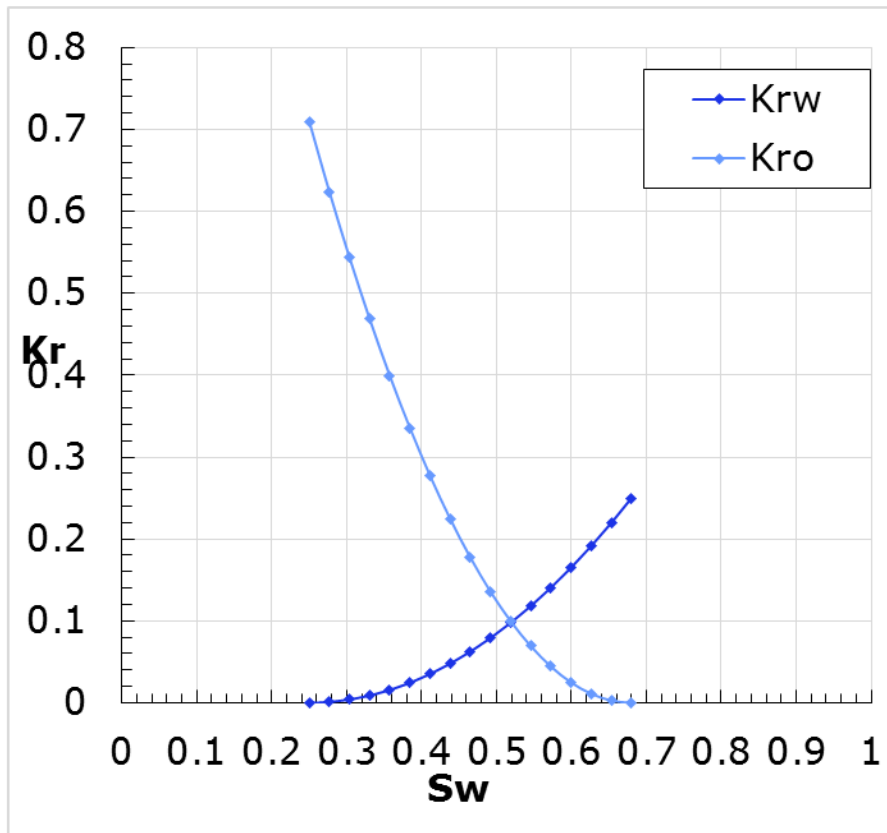


Modeling Approach(Cont'd)



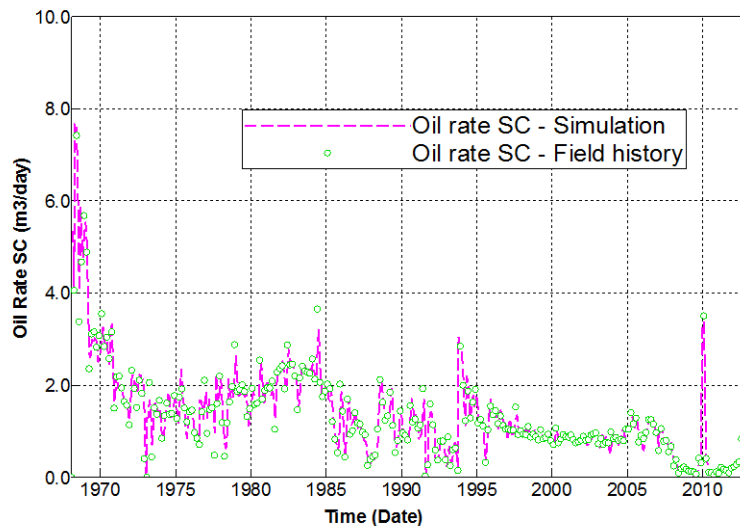
Three horizons and well location

Relative Permeability Curves

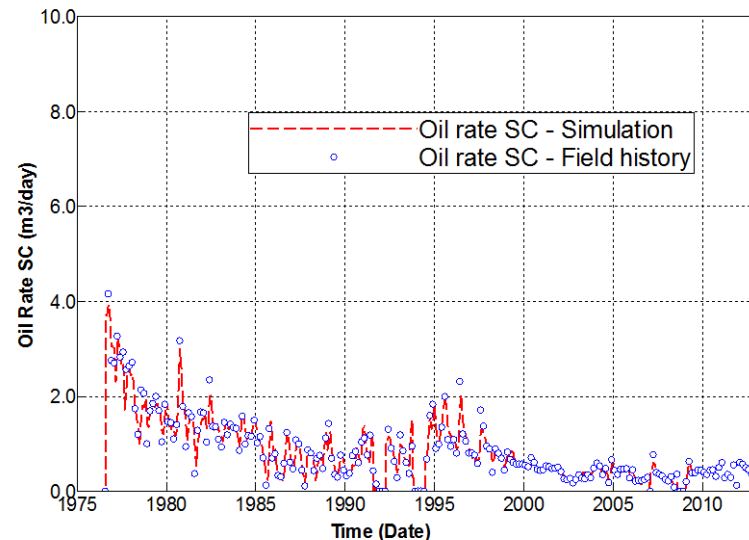


Modeling Approach(Cont'd)

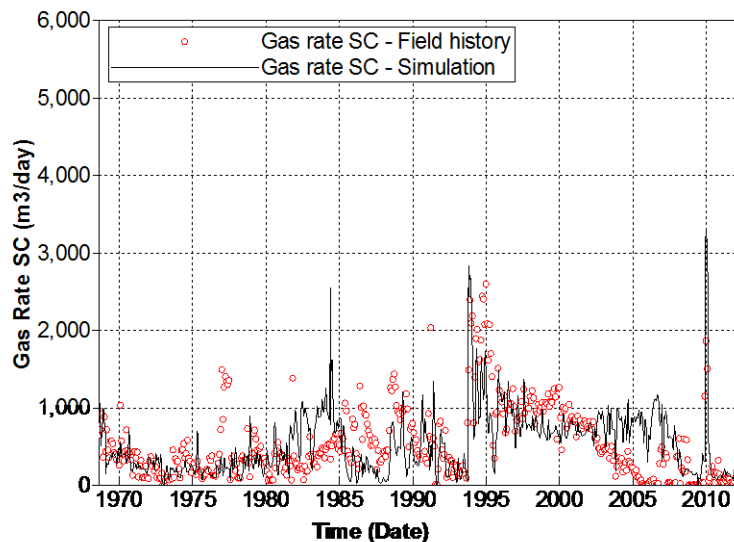
❖ History Matching the vertical wells



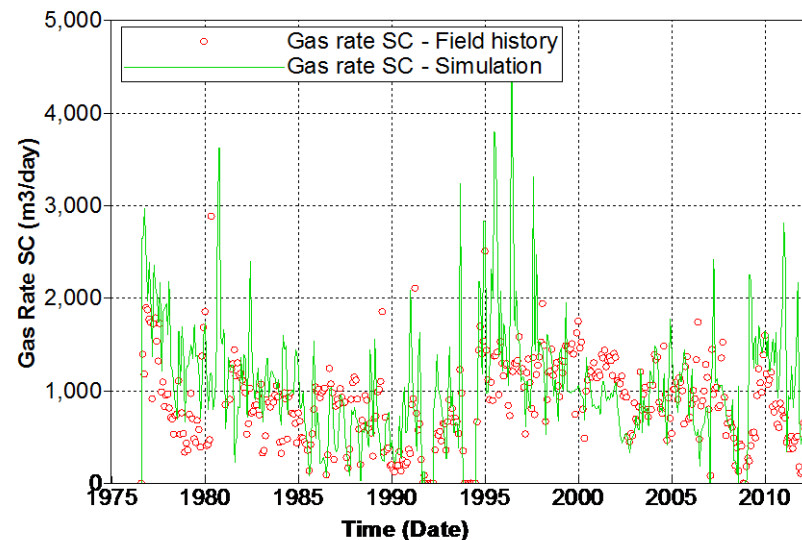
a). Oil rate of well 1



b). Oil rate of well 2



a). Gas rate of well 1

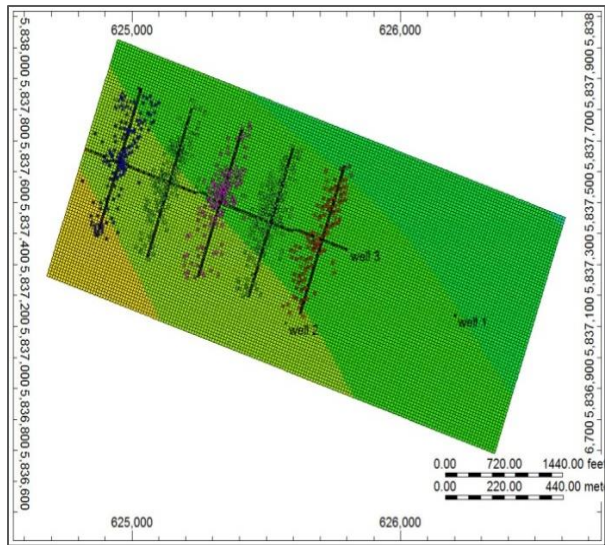


b). Gas rate of well 2

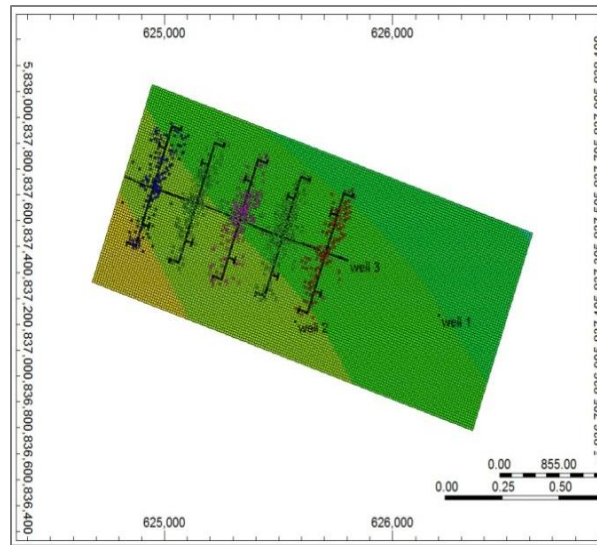
Modeling Approach(Cont'd)

❖ Synthetic Fracture Geometries

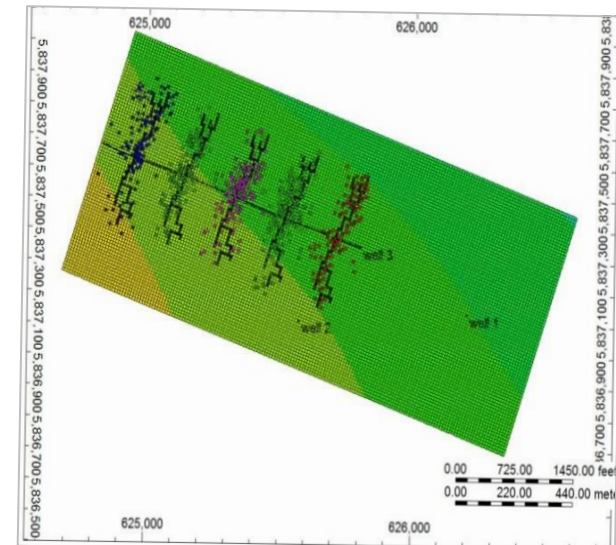
- Fracture space is 200 m;
- Same fracture volume for every scenario;
- When a main fracture is divided into two halves, fracture permeability becomes one fourth of previous values.



Scenario 1: Simple planar fractures



Scenario 2: branches with planar fractures



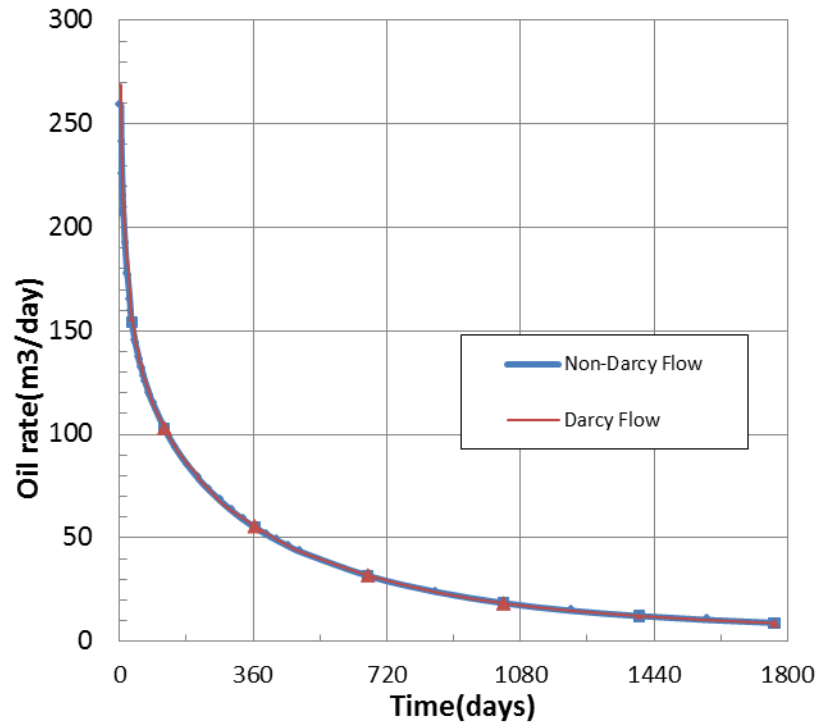
Scenario 3: complex fractures

Outline

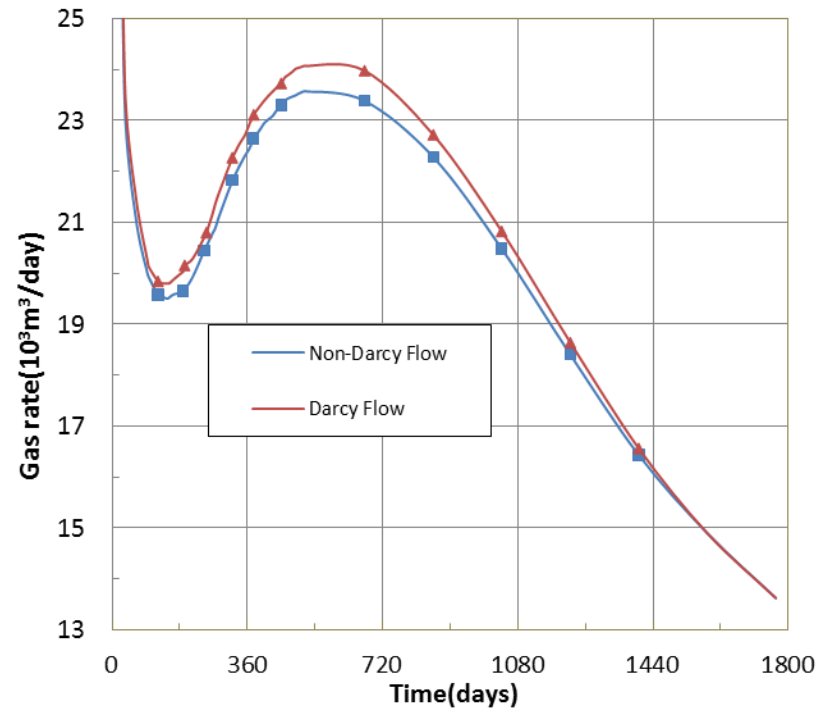
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Results and Discussion

❖ Non-Darcy Effect in fractures



oil production

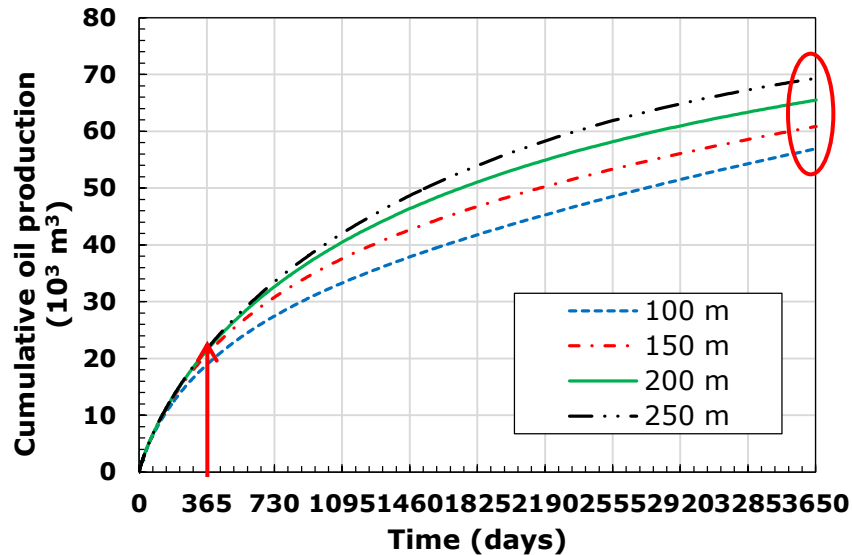


gas production

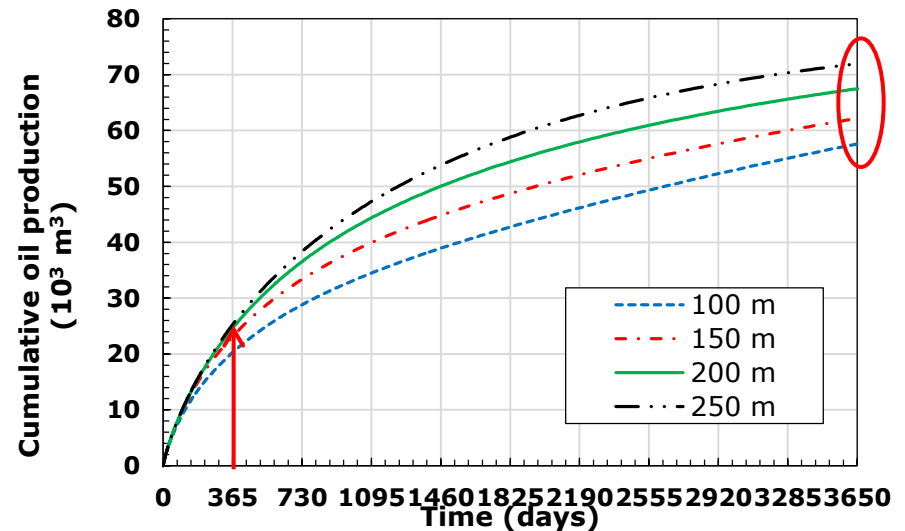
Comparison of Darcy flow and non-Darcy flow in simple planar fractures with conductivity of 500D•mm

❖ Effect of Fracture Half-length and Conductivity

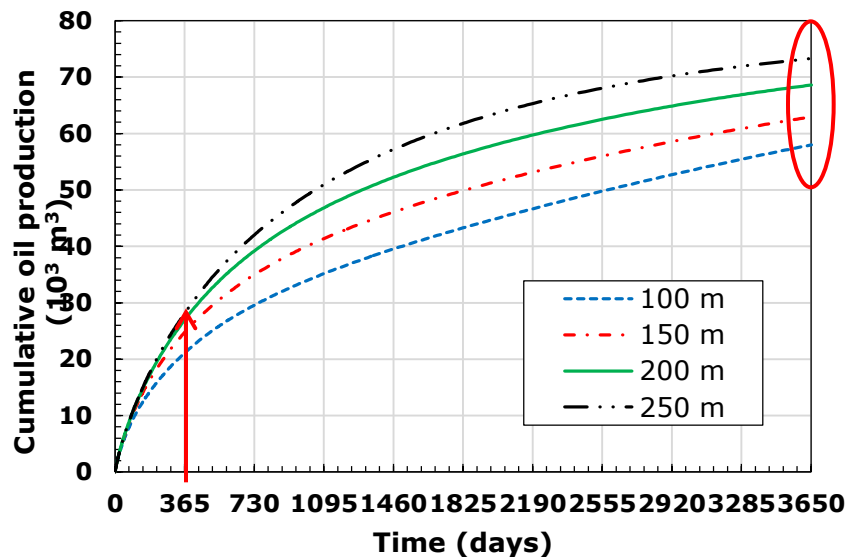
Ideal Bi-wing Fractures



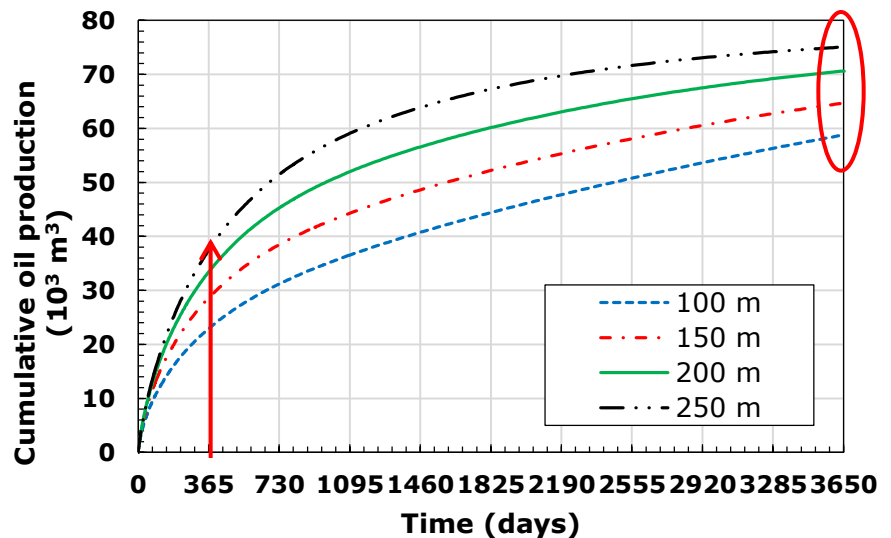
Fracture conductivity 100D-mm



Fracture conductivity 150D-mm



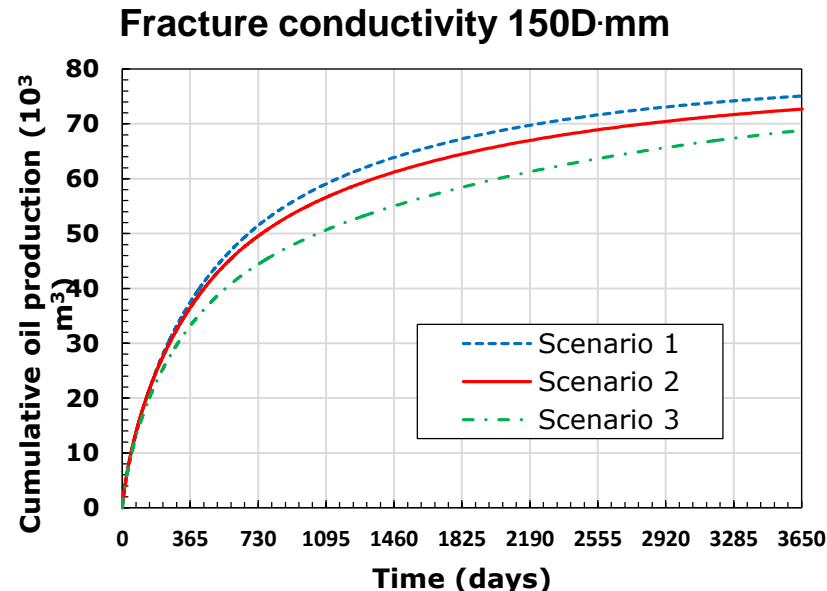
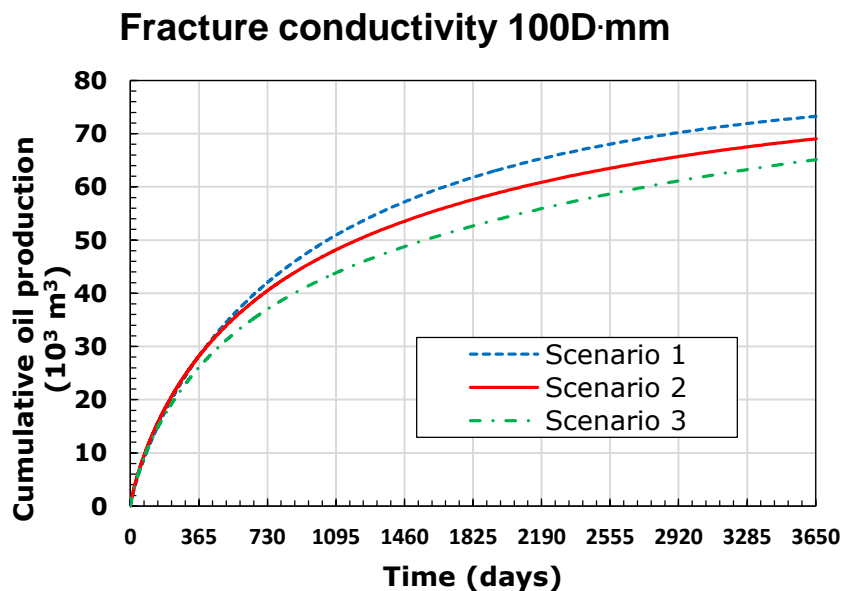
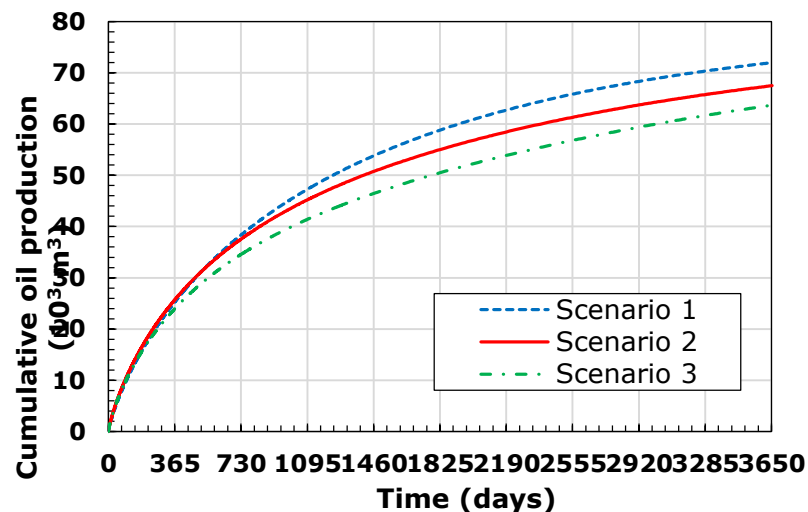
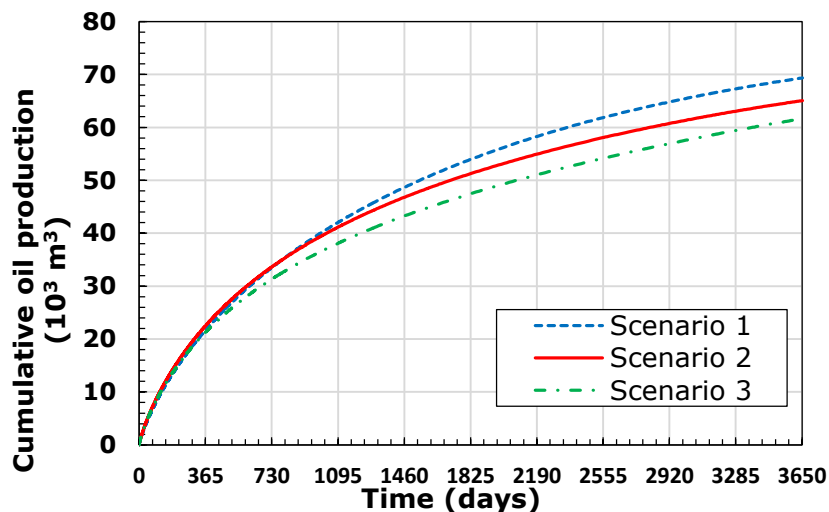
Fracture conductivity 200D-mm



Fracture conductivity 500D-mm

❖ Effect of Fracture Geometry

Secondary-main fracture permeability ratio: 1/4; conductivity ratio: 1/8

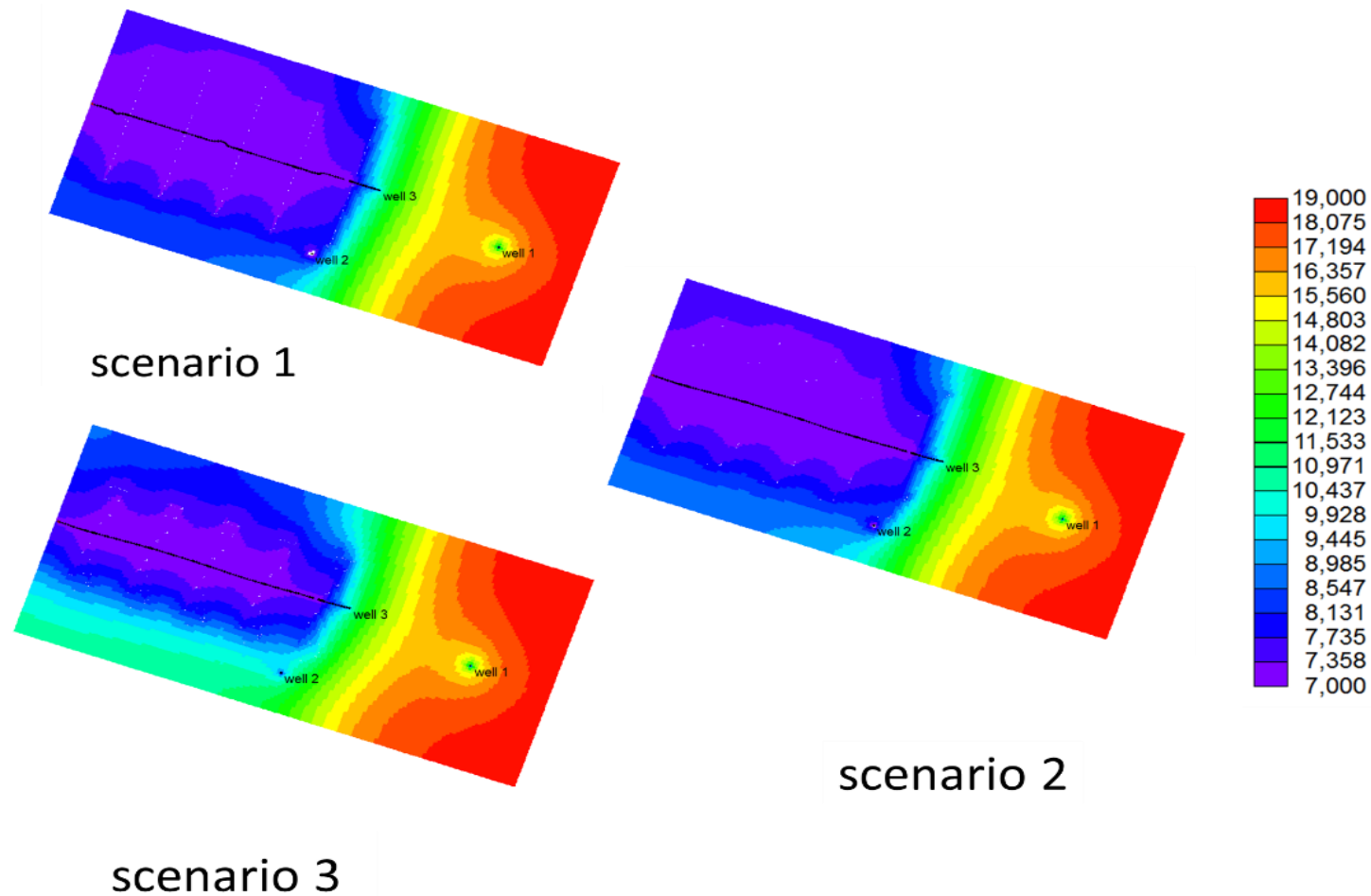


Fracture conductivity 200D-mm

Fracture conductivity 500D-mm

❖ Effect of Fracture Geometry

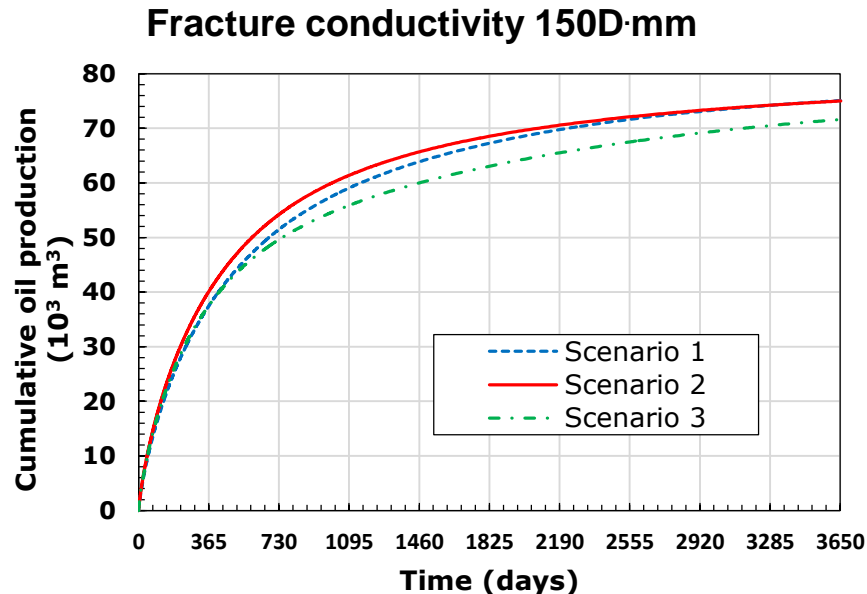
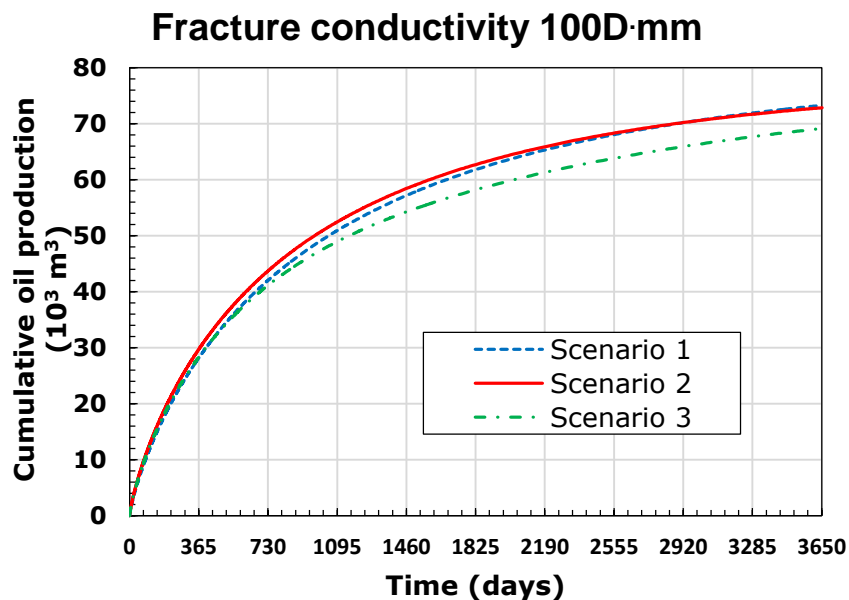
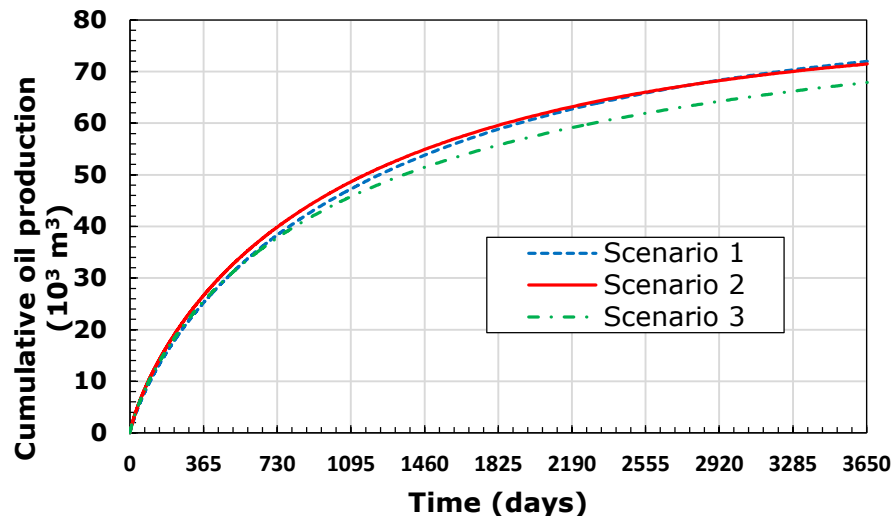
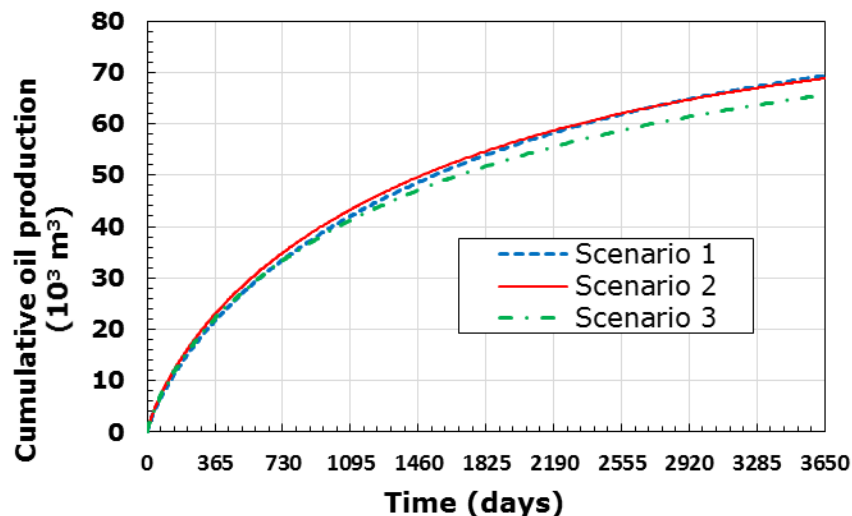
Secondary-main fracture permeability ratio: 4:1; conductivity ratio: 1/8



Pressure distribution after 10 years (main fracture conductivity: 500 D·mm; secondary-main fracture permeability ratio: 1/4; conductivity ratio: 1/8)

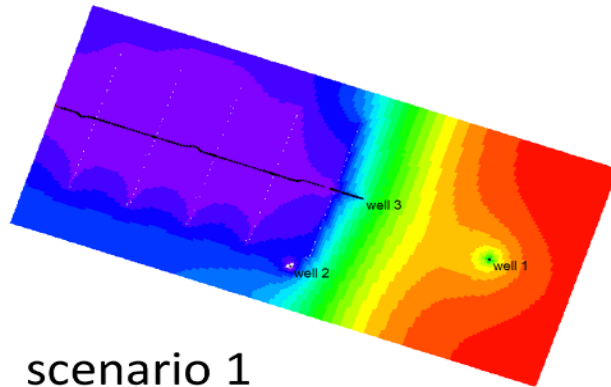
❖ Effect of Fracture Geometry

Secondary-main fracture permeability ratio: 1:1; conductivity ratio: 1/2

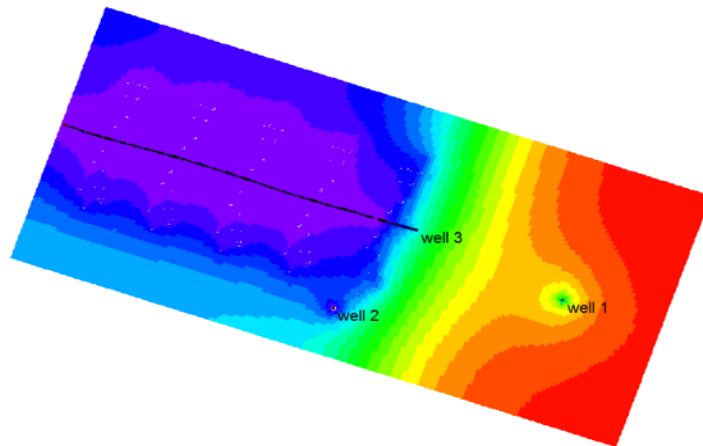


❖ Effect of Fracture Geometry

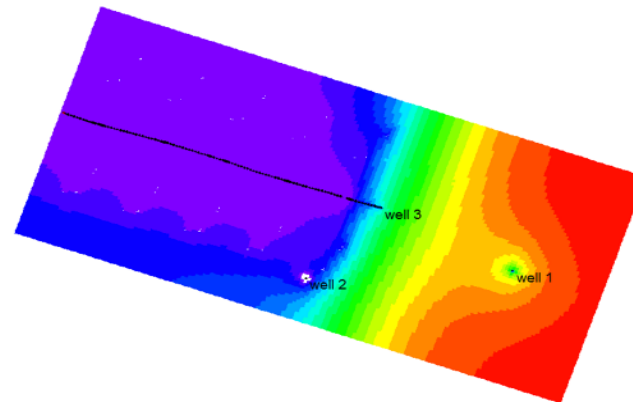
Secondary-main fracture permeability ratio: 1:1; conductivity ratio: 1/2



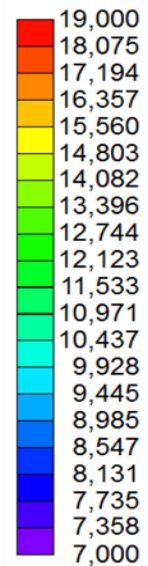
scenario 1



scenario 3



scenario 2



Pressure distribution after 10 years (main fracture conductivity: 500 D·mm; secondary-main fracture permeability ratio: 1:1; conductivity ratio: 1/2)

Conclusions

1. Three fracture geometries, simple planar fractures, branching fractures, and fracture network are simulated in this study. It is found that commonly used simple planar fractures overestimate the well productivity if a complex fracture network is created in the reservoir.
2. For the ideal bi-wing fractures, main fracture conductivity plays an essential role in the early period, while fracture half-length can significantly affect the long term production.
3. For different fracture geometries, the early production is similar (e.g. cumulative production of the first 6 months) and the differences arise around the end of the first year.

Conclusions

4. Conductivity of the secondary fracture plays an important role on the after-stimulation well productivity. Secondary fractures with low conductivity can decrease the well productivity compared to that of the wells with bi-wing planar fractures.
5. If a fracture network is intended to be created in the reservoir, efforts must be made to achieve high conductivity of the secondary fractures. Under such circumstance, adding some complexity to the fracture geometry can increase well production (e.g. scenario 2 under the conductivity ratio of one-half), which is due to a larger contact area between matrix and fracture.
6. However, even with high secondary fracture conductivity, a complicated fracture geometry (scenario 3) still leads to a low long term production. This is owing to the shortened length of the main fracture.

Acknowledgement

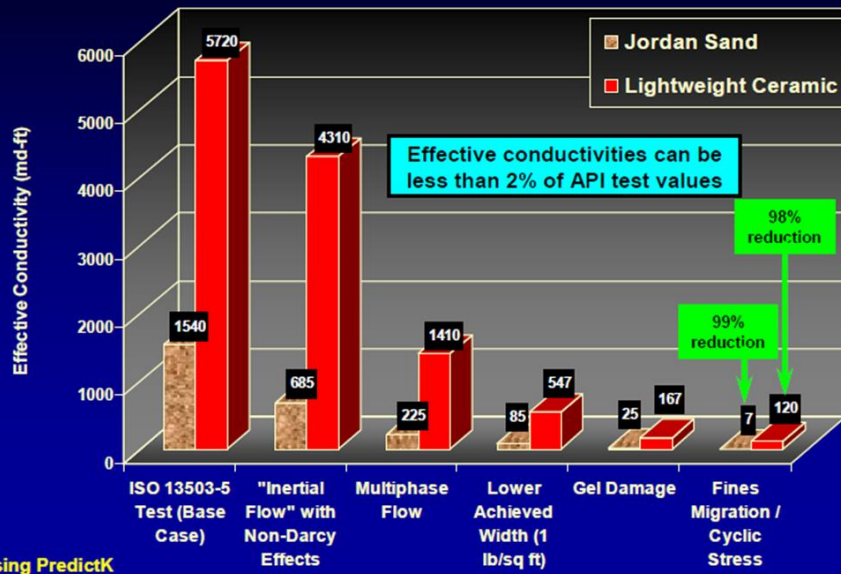
Sponsors of this study



Thank you

Range of Fracture Conductivity

Cumulative Conductivity Reductions



Reduction of actual fracture conductivity

Fig a. Source: SPE 106301

Range: 100-500 D-mm

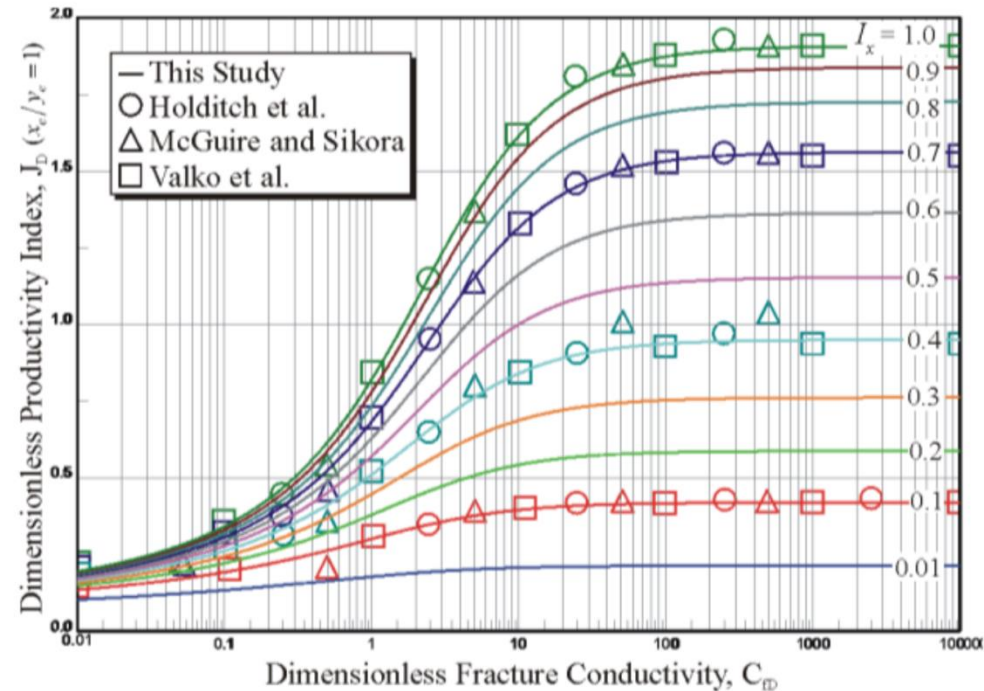
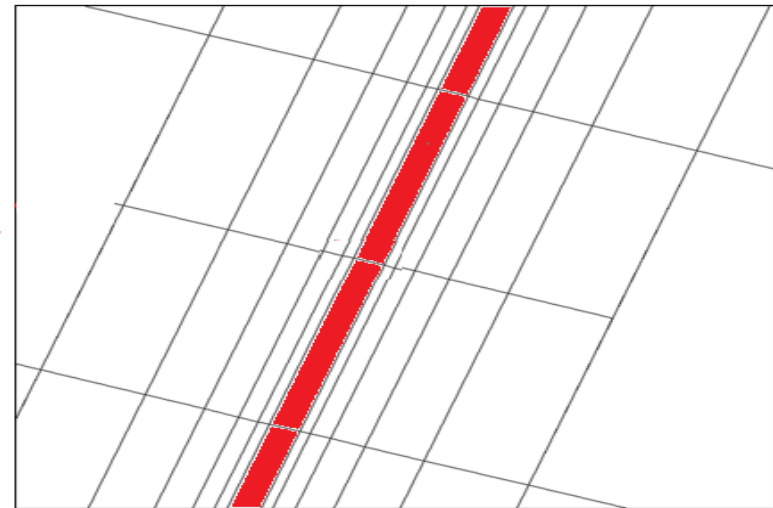
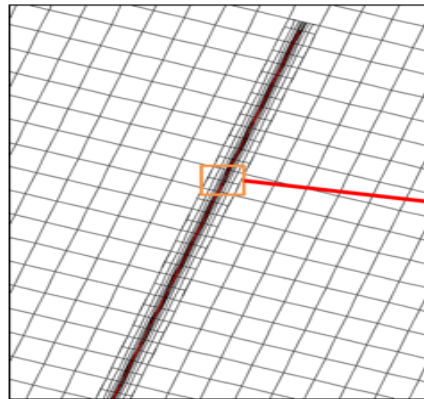
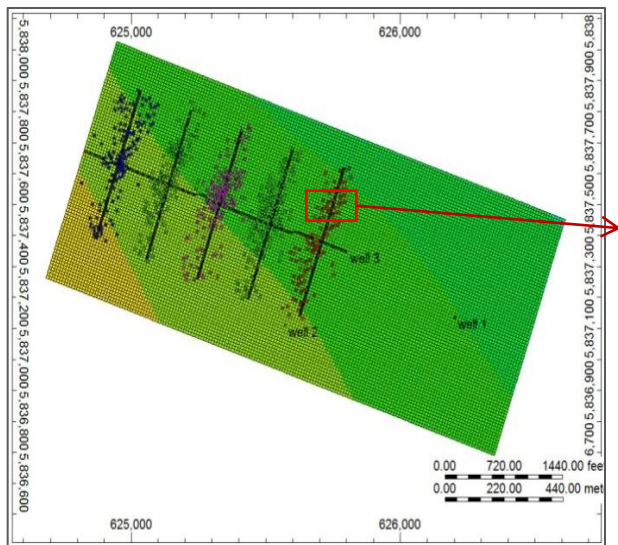


Fig b. Source: SPE 165702

Modeling Approach(Cont'd)

Local Grid Refinement



$$k_f \times w_f = k_e \times w_{block}$$
$$k_e = \frac{k_f \times w_f}{w_{block}}$$
$$= \frac{15000 \text{ md} \times 0.01 \text{ m}}{0.6 \text{ m}} = 250 \text{ md}$$